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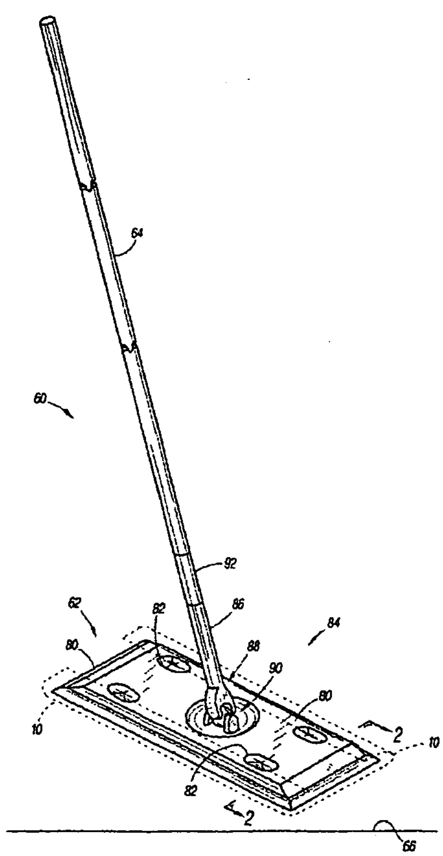
(54) Title: PARTICLE ENTRAPMENT SYSTEM




(57) Abstract: A cleaning sheet for cleaning and removing particles from a surface is disclosed. The cleaning sheet includes a particle retention layer for collecting and retaining the particles. The particle retention layer includes electret wax deposited on at least a portion of the layer.

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# PARTICLE ENTRAPMENT SYSTEM

## BACKGROUND

Dust cloths for removing dust from a surface to be cleaned, such as a table, are generally known. Such known dust cloths are typically made of woven or non-woven fabrics and are often sprayed or coated with a wet, oily substance for retaining the dust. However, such known dust cloths tend to leave an oily film on the surface after use.

Other known dust cloths include non-woven entangled fibers having spaces between the entangled fibers for retaining the dust. The entangled fibers are typically supported by a network grid or scrim structure, which can provide additional strength to such cloths. However, such cloths can become saturated with the dust during use (i.e., dust buildup) and/or may not be completely effective at picking up dense particles, large particles or other debris.

Accordingly, it would be advantageous to provide a cleaning sheet that can pick up and retain dust and debris. It would also be advantageous to provide a cleaning sheet that has an enhanced dust collection capacity. It would also be advantageous to provide a cleaning sheet that attracts debris without the use of an oily spray. It would also be advantageous to provide a cleaning sheet that retains relatively large and/or denser particles of debris. It would further be advantageous to provide a cleaning sheet including any one or more of these or other advantageous features.

## SUMMARY

The present invention relates generally to the field of cleaning sheets, such as for use in cleaning surfaces (e.g., in the home or work environment). More particularly, the invention relates to a cleaning sheet for collecting and retaining dust, larger particles and/or other debris.

A particle entrapment system or cleaning sheet is provided. The cleaning sheet is useful for cleaning and removing particles and other debris from a surface such as a table, floor, article of furniture or the like. The cleaning sheet may include a number of layers or sheets to increase debris retention and/or strength. The sheet typically includes a particle retention layer (e.g., base layer) including electret material for collecting and retaining the particles. The electret material may be electret wax that is deposited on and/or impregnated in at least a portion of the particle retention layer.

The sheet may also include an outer layer (e.g., cover layer) covering at least a portion of the particle retention layer. The cover layer may include a plurality of apertures, which allow the debris to be forced and/or attracted therethrough. The apertures may make up a substantial portion of the cover layer, and may typically have a cross-sectional dimension of at least about 1.0 $mm^2$. Examples of suitable cover layers include materials having a plurality of apertures with an average cross-sectional dimension of about 1.0 to about 10.0 $mm^2$. The cover layer is commonly formed from a low dust retention material (e.g., perforated sheets formed from polytetrafluoroethylene ("PTFE")). The cover layer comprises a low dust retention material and includes a surface having a plurality of apertures formed therethrough.

Cleaning utensils incorporating the cleaning sheet are also provided. The utensil may include a cleaning head adapted for coupling to the cleaning sheet. The cleaning sheet(s) may also be packaged as part of a cleaning utensil kit for cleaning surfaces. The kit may include a cleaning head adapted for coupling to the sheet and a handle adapted for coupling to the cleaning head.

A method of cleaning a surface is also provided. The method includes contacting a surface to be cleaned with the cleaning sheet. The debris from the surface to be cleaned may be drawn and/or forced into the particle retention layer and retained by the cleaning sheet.

In various embodiments of the cleaning sheet, the particle retention layer may be a cover layer, a backing sheet or layer or a core layer. The particle retention layer may be a uniform, planar sheet, or a contoured surface including protrusions and depressions. An electret material, such a wax that has been rendered electret, is typically deposited on and/or impregnated into at least portions of the particle retention layer to enhance its particle collection and/or retention capabilities.

A method of making a cleaning utensil for collecting and retaining debris is also provided. The method includes forming a cleaning sheet that includes particle retention material such as woven fiber, non-woven fiber and/or foam. The method includes applying non-electret wax to at least a portion of the particle retention material. An electric field is applied to sheet to induce a permanent electric charge in at least the wax. This can commonly be accomplished by heating the sheet to a temperature sufficient to melt the wax without substantially softening the particle retention material. While the

wax is still in a molten state, an electric field is applied to sheet. The electric field is of sufficient magnitude and duration to cause the wax to become electrically charged. For example, this can be accomplished by passing the sheet with the molten wax through a corona discharge. The charged wax is then cooled to solidify the wax thereby rendering it relatively permanently charged.

The present sheets can also be formed via a method in which molten wax is subjected to an electric field as the wax is being applied to the particle retention material. For example, molten wax can be sprayed onto portions of a layer of particle retention material in a continuous or discontinuous pattern in such a manner that the wax passes through an electric field while still in a molten state. It is generally advantageous to hold the particle retention material at a low enough temperature such that the wax solidifies on contact (or shortly thereafter) with the material.

The cleaning sheet typically has a relatively low overall breaking strength in order to preserve a relative amount of flexibility. The term "breaking strength" as used in this disclosure means the value of a load (i.e., the first peak value during the measurement of the tensile strength) at which the cleaning sheet begins to break when a tensile load is applied to the cleaning sheet. The breaking strength of the sheet should, however, be high enough to prevent "shedding" or tearing of the cleaning sheet during use. The breaking strength of the cleaning sheet is typically at least about 500 g/30 cm and cleaning sheets with breaking strengths of 1,500 g/30 cm to 4,000 g/30 cm are quite suitable for use with the cleaning implements described herein.

When intended to be used with a cleaning utensil, mounting structure or the like, the cleaning sheet typically has a relatively low overall elongation to assist in resisting "bunching" or "puckering" of the cleaning sheet. The term "elongation" as used in this disclosure means the elongation percentage (%) of the cleaning sheet when a tensile load of 500 g/30 mm is applied. For example, when designed to be used in conjunction with a mop or similar cleaning implement where the cleaning sheet is fixedly mounted, the present cleaning sheets typically have an elongation of no more than about 25% and, preferably, no more than about 15%.

The terms "surface" and "surface to be cleaned" as used in this disclosure are broad terms and are not intended as terms of limitation. The term surface as used in this disclosure includes substantially hard or rigid surfaces (e.g., articles of furniture,

tables, shelving, floors, ceilings, hard furnishings, household appliances, and the like), as well as relatively softer or semi-rigid surfaces (e.g., rugs, carpets, soft furnishings, linens, clothing, and the like).

The term "debris" as used in this disclosure is a broad term and is not intended as a term of limitation. In addition to dust and other fine particulate matter, the term debris includes relatively large-sized particulate material, e.g., having an average diameter greater than about 1 mm, such as large-sized dirt, food particles, crumbs, soil, sand, lint, and waste pieces of fibers and hair, which may not be collected with conventional dust rags, as well as dust and other fine particulate matter.

Throughout this disclosure, the text refers to various embodiments of the cleaning sheet and/or methods of using or forming the sheet. The various embodiments discussed are merely illustrative and are not meant to limit the scope of the present invention. The various embodiments described are intended to provide a variety of illustrative examples and should not necessarily be construed as descriptions of alternative species since the descriptions of the various embodiments may be of overlapping scope.

## BRIEF DESCRIPTION OF THE FIGURES

FIGURE 1 is a perspective view of a cleaning utensil according to an exemplary embodiment.

FIGURE 2 is a cross-sectional view of a cleaning sheet taken along line 2-2 of FIGURE 1 according to an exemplary embodiment.

FIGURE 3 is a fragmentary partially exploded sectional view of a cleaning sheet according to another exemplary embodiment.

FIGURE 4 is a fragmentary partially exploded sectional view of a cleaning sheet according to another exemplary embodiment.

FIGURE 5 is a fragmentary partially exploded sectional view of a cleaning sheet according to another exemplary embodiment.

FIGURE 6 is a top plan view of a scrim according to a suitable embodiment.

FIGURE 7 is a fragmentary top plan view of the cleaning sheet according to a suitable embodiment.

FIGURE 8 is a fragmentary top plan view of a hole of a cleaning sheet according to a suitable embodiment of the present invention.

FIGURE 9 shows a stress-strain curve where the vertical axis represents the stress, the horizontal axis represents the strain, and O represents the origin.

FIGURE 10 is a sectional view of an apparatus for rendering a wax electret.

FIGURE 11 is a sectional view of an electret wax formed by the apparatus shown in FIGURE 10.

FIGURE 12 is a sectional view of a cleaning sheet including an electret layer and a micro-fiber layer.

FIGURE 13 is a top plan view of a cleaning sheet including an electret wax distributed in a discontinuous pattern.

FIGURE 14 is a sectional view of a cleaning sheet including an electret wax distributed in a row pattern.

FIGURE 15 is a sectional view of the cleaning sheet of FIGURE 3 showing an electret wax deposited in a depression of a particle retention layer.

## DETAILED DESCRIPTION

One example of a cleaning sheet (shown as a dusting pad 10) for collecting, attracting and retaining particulate matter and other debris (e.g., dust, soil, other airborne matter, lint, hair, etc.) is shown in FIGURE 1. Pad 10 includes an "electret" base or core particle retention layer 30 permanently charged with an electrostatic force for attracting (e.g., collecting) and retaining particulate matter (shown as debris 68 in FIGURE 2). Debris 68 is drawn and/or forced into the particle retention layer 30 when pad 10 is moved along a surface to be cleaned (shown as a work surface 66 in FIGURE 1). Pores (shown as cavities 34) of core 30 retain and/or entrain debris 68 within cavities 32 of pad 10 (see, e.g., FIGURE 2).

The particulate matter may be further retained by a cover sheet, which can cover or surround all or a portion of the electret material, to "trap" and retain the particulate matter in the electret material. An outer or cover layer 20 may be made of a material that has a relatively low debris retention capacity (i.e., that does not significantly attract or collect the debris), and generally has a lower debris retention than the core, so the exterior surface of cover layer 20 remains substantially free of debris 68. Examples of exemplary materials that do not significantly collect dust include perforated sheets formed from polytetrafluoroethylene. Typically, the cover layer is configured to retain

no more than about 10 g/m² of particulate matter, more suitably no more than about 1 to 5 g/m².

1. PARTICLE RETENTION LAYER

The present cleaning sheet includes a particle retention layer, at least a portion of which includes electret material (i.e., has been rendered permanently electrically charged). The sheet can include core 30 which includes a particle retention surface 32 located within pad 10 adjacent cover layer 20. In other embodiments, the cleaning sheet may simply consist of the particle retention layer (e.g., a scrim-supported layer of non-woven microfibers and at least portion of which have been coated with an electret wax). Cavities 34 of particle retention surface 32 trap, collect and retain a significant amount of debris 68. For example, debris may be embedded against a wall of the cavity. According to suitable embodiments, the particle retention layer may be a shaped fabric, a continuous sheet of flexible material, or multiple sheets of material. Referring to FIGURE 2, cavities 34 can be formed from pores randomly distributed in core 30. Cavities 34 having a circular shape, but may be any shape or combination of shapes such as rounded, jagged, irregular, etc. as shown in FIGURE 2. For example, the cavities may be rectangular, star, oval, or irregular shaped. The cavities may be disposed in a regular pattern, as depicted in FIGURE 3 and may be randomly arranged.

The size and depth of the cavities should preferably be large enough to create a sufficient sized "pocket" or cavity to keep entrained debris from scratching or damaging the surface being cleaned. The cavities are preferably not so deep, however, that it is difficult for debris to be brought into contact with the cavity. The cavities typically have an average width in the range of about 1 to 10 mm, more suitably 2 to 5 mm, depending in part on the size of the particles intended to be retained. The cavities typically have an average depth in the range of about 0.1 to 5 mm, more suitably 1 to 3 mm.

FIGURE 3 shows a sectional view of a pad 110, an exemplary embodiment of the cleaning sheet. Pad 110 differs substantially from pad 10 in one respect: the structure of core 30 is changed. Other than this modification, the construction, performance and function of pad 110 shown in FIGURE 3 is substantially the same as pad 10, and like reference numerals are used to identify like elements. A core 130 of pad 110 is textured to form the pores (shown as depressions 134). Protrusions (shown

as outwardly extending, flexible, semi-rigid fingers 136) extend from core 130 toward cover layer 20. Fingers 136 are generally rectangular shaped, but may be of other shapes (e.g., zigzag, rounded, wave-like, etc.) according to other embodiments. Fingers 136 are shown arranged in a row-like pattern, but may be arranged in other patterns or configurations (e.g., circular, random, etc.) according to other suitable embodiments. Fingers 136 define depressions 134 for retaining debris 68 (e.g., between two protrusions). When retained inside depressions 134, debris 68 is substantially prevented from escaping the interior of pad 110 by cover layer 20.

FIGURE 4 shows a pad 210, another exemplary embodiment of the cleaning sheet. Pad 210 differs substantially from pad 10 in two respects: the structure of core 30 is changed, and the material of core 30 is changed. Other than these modifications, the construction, performance and function of pad 210 is substantially the same as pad 10, and like reference numerals are used to identify like elements. A core 230 of pad 210 is shaped (e.g., as a sinusoidal wave) to form the pores (shown as depressions 234) for retaining debris 68. A top cover layer 20 "sandwiches" or presses core 230 against a bottom cover layer 20. Protrusions (shown as projections 236) extend from core 230 to form depressions 234. Projections 236 are generally blunt shaped and include an inclined or sloping wall 240. The sloping shape of projections 236 provides additional surface area in depressions 234 for collecting and retaining debris 68. As shown in FIGURE 4, projections 236 are arranged in a row-like or corrugated pattern. Projections 236 of a top particle retention surface 232 are shown arranged in an alternating pattern, such that projections 236 of surface 232 correspond to depressions 234 of a bottom particle retention surface 238. According to other suitable embodiments, the protrusions (i.e., projections) and the pores (i.e., depressions) may be arranged in a variety of other patterns (e.g., protrusions of the top particle retention surface corresponding to the protrusions of the bottom particle retention surface and arranged in a row-like or wave-like manner). According to other suitable embodiments (as shown in FIGURES 4 and 5) the particle retention layer (i.e., core) includes at least two sides, and the pores (i.e., cavities) are arranged on each side of the particle retention layer.

FIGURE 5 shows a pad 310, another exemplary embodiment of the cleaning sheet. Pad 310 differs substantially from pad 10 in two respects: the structure of core

30 is changed, and the materials of core 30 are changed. Other than these modifications, the construction, performance and function of pad 310 is substantially the same as pad 10, and like reference numeral are used to identify like elements. Core 330 of pad 310 is shown made of an entangled network of non-woven fibers. The pores for trapping the debris are formed by the spaces between the entangled fibers (i.e., the debris is retained between the fibers that form the core). According to other suitable embodiments, the core may be made from a variety of combinations of materials formed in a variety of structures.

The term "non-woven" as used in this disclosure includes a web having a structure of individual fibers or threads which are interlaid, but not necessarily in a regular or identifiable manner as in a knitted fabric. The term also includes individual filaments and strands, yarns or "tows" as well as foams and films that have been fibrillated, apertured, or otherwise treated to impart fabric-like properties. Non-woven fabrics or webs have been formed from many processes such as for example, meltblowing processes, spunbonding processes, and bonded carded web processes. The basis weight of non-woven fabrics is usually expressed in ounces of material per square yard ("osy") or grams per square meter ("gsm") and the fiber diameters useful are usually expressed in microns. Basis weights can be converted from osy to gsm simply by multiplying the value in osy by 33.91. According to another suitable embodiment, the fibers may be woven.

According to an exemplary embodiment, a web or lattice (shown as a scrim 50 in FIGURE 6) may support the fibers of a non-woven sheet. This allows the production of sheets that have a relatively low entanglement coefficient (e.g., no more than about 800 m) while retaining sufficient strength to be used for cleaning. As shown in FIGURE 5, scrim may be integrally embedded within the fibers to form a unitary support structure. In FIGURE 6 scrim 50 includes a net having horizontal members 52 attached to vertical members 54 arranged in a "network" configuration. Spaces (shown as holes 56) are formed between vertical members 54 and horizontal members 52 to give scrim 50 a mesh or lattice-like structure. According to various embodiments, the horizontal and vertical members of the scrim may be connected together in a variety of ways such as woven, spot welded, cinched, tied, etc. The average diameter of holes 56 generally falls within the range of 20 to 500 mm, and more suitably between 100 to 200

mm. The distance between the fibers typically falls within about 2 to 30 mm, and more suitably within about 4 to 20 mm. Alternatively, the nonwoven sheet may be reinforced by filaments embedded in the sheet which are held in place simply by the mechanical forces resulting from hydroentangling microfibers around the filaments.

The fibers may be overlaid on each side of scrim 50 to attach the fibers to scrim 50, thereby forming pad 310 as a unitary piece or structure. A low-pressure water jet may be subsequently applied to entangle the fibers to each other and to scrim 50 (i.e., hydroentanglement) to form a relatively lose entanglement of non-woven fibers. Hydroentanglement of the fibers may be further increased during removal (e.g., drying) of the water from the water jet. (The scrim may also "shrink" somewhat during drying to create a fabric having a "puckered" or contoured surface.) The fibers may also be attached to the web (i.e., scrim) by a variety of other conventional methods (e.g., air laid, adhesive, woven, etc.). The fibers are typically entangled onto the web to form a unitary body, which assists in preventing "shedding" of the fibers from the web during cleaning. The web may be formed from a variety of suitable materials, such as polypropylene, nylon, polyester, etc. An exemplary web (i.e., scrim) is described in U.S. Patent No. 5,525,397, the disclosure of which is hereby incorporated by reference.

The degree of entanglement of the fibers in the core can be measured by an "entanglement coefficient". The entanglement coefficient is also referred to as the "CD initial modulus". The term "entanglement coefficient" as used in this disclosure refers to the initial gradient of the stress-strain curve measured with respect to the direction perpendicular to the fiber orientation in the fiber aggregate (cross machine direction). The term "stress" as used in this disclosure means a value which is obtained by dividing the tensile load value by the chucking width (i.e., the width of the test strip during the measurement of the tensile strength) and the basis weight of the non-woven fiber aggregate. The term "strain" as used in this disclosure is a measure of the elongation of the cleaning sheet material.

Suitable non-woven fiber aggregates for use in forming the cleaning sheet have an entanglement coefficient in the range of about 20 to 500 m (as measured after any reinforcing filaments or network has been removed from the non-woven fibrous web) and, more typically, no more than about 250 m. A small value of the entanglement coefficient generally represents a smaller degree of entanglement of the fibers. The

entanglement coefficient may be controlled in part by selection of the type and quantity of fibers, the weight of the fibers, the amount and pressure of the water, etc. (See U.S. Patent No. 5,525,397 at col. 4, line 52 - col. 5, line 26 discussing entanglement of fibers.)

The core (e.g., core 330 as shown in FIGURE 5) may include a non-woven aggregate layer having fibers with a large degree freedom and sufficient strength, which may be advantageous for effectively collecting and retaining dust and larger particulates within the cleaning sheet. In general, a non-woven fabric formed by the entanglement of fibers involves a higher degree of freedom of the constituent fibers than in a non-woven fabric formed only by fusion or adhesion of fibers. The non-woven fabric formed by the entanglement of fibers can exhibit better dust collecting performance through the entanglement between dust and the fibers of the non-woven fabric. The degree of the entanglement of fibers can have a large effect on the retention of dust. That is, if the entanglement becomes too strong, the freedom of fibers to move will be lower and the retention of dust is generally decreased. In contrast, if the entanglement of the fibers is very weak, the strength of the non-woven fabric can be markedly lower, and the processability of the non-woven fabric may be problematic due to its lack of strength. Also, shedding of fibers from the non-woven fabric is more likely to occur from a non-woven aggregate with a very low degree of entanglement.

A suitable non-woven aggregate for use in producing the present cleaning sheet can be formed by hydroentangling a fiber web (with or without embedded supporting filaments or a network sheet) under a relatively low pressure. For example, the fibers in a carded polyester non-woven web can be sufficiently entangled with a network sheet by processing the non-woven fiber webs with water jetted at high speed under about 25-50 kg/cm$^3$ of pressure. The water can be jetted from orifices positioned above the web as it passes over substantially smooth non-porous supporting drum or belt. The orifices typically have a diameter ranging between 0.05 and 0.2 mm and can be suitably arranged in rows beneath a water supply pipe at intervals of 2 meters or less.

In cases where the entanglement coefficient of the fiber aggregate is to be set at a maximum value of about 800 m, it may be difficult for a sheet, which is constituted only of a fiber aggregate, to achieve the values of sufficient breaking strength and the elongation. By entangling the fibers to scrim 50 into a unitary body, and the elongation

of this layer is kept low and its processability can be enhanced. Shedding of the fibers from the cleaning sheet can often be markedly prevented as compared with a conventional entangled sheet, which is constituted only of a fiber aggregate in approximately the same entanglement state as that in the fiber aggregate of the cleaning sheet.

If the entanglement coefficient is too small (e.g., no more than about 10 to 20 m), the fibers will not be sufficiently entangled together. In addition, the entanglement between the fibers and the scrim will likely be poor as well. As a result, shedding of the fibers may occur frequently. If the entanglement coefficient is too large (e.g., greater than about 700 to 800 m), a sufficient degree of freedom of the fibers cannot be obtained due to too strong entanglement. This can prevent the fibers from easily entangling with dust, hair and/or other debris, and the cleaning performance of the sheet may not be satisfactory.

The cleaning sheet typically includes a non-woven fiber aggregate as a core layer having a relatively low basis weight. The basis weight of the non-woven fiber aggregate generally falls within the range of 30 to 100 g/m$^2$ and, typically is no more than about 75 g/m$^2$. If the basis weight of the non-woven fiber aggregate is less than about 30 g/m$^2$, dust may pass too easily through the non-woven fiber aggregate during the cleaning operation and its dust collecting capacity may be limited. If the basis weight of the non-woven fiber aggregate is too large (e.g., substantially greater than about 150 g/m$^2$), the fibers in the non-woven fiber aggregate (if any) generally may not be sufficiently entangled with each other to achieve a desirable degree of entanglement. In addition, the processability of the non-woven fiber aggregate can worsen, and shedding of the fibers from the cleaning sheet may occur more frequently. The denier of the fibers in the non-woven fiber aggregate, the length, the cross-sectional shape and the strength of the fibers used in the non-woven fiber aggregate are generally determined with an eye toward processability and cost, in addition to factors relating to performance.

The cleaning sheet typically includes an outer non-woven fiber layer or net/web that has a relatively low basis weight as an outer fabric layer (i.e., the material on the cleaning surface of the sheet). According to a particularly suitable embodiment, the non-woven layer or net has a basis weight in the range of about 20 to 150 g/m$^2$,

preferably 30 to 75 g/m$^2$. A low basis weight can assist in providing a "stream-line" or compact look and feel to the cleaning sheet. The basis weight of the cleaning sheet may be about 50 to 250 g/m$^2$ (or greater or lesser depending on the intended use for the cleaning sheet).

The cleaning sheet may include a non-woven fabric formed from fibers or micro-fibers. The term "denier" as used in this disclosure is defined as the weight in grams of a 9000 meter length of fiber. The denier of the fibers of the particle retention layer is suitably about 0.1-6, more suitably about 0.5-3.

a. Electrostatic Properties of the Particle Retention Layer

The particle retention lay may include a dielectric material that may be rendered "electret" in whole or in part. Electrets retain an electrostatic charge over a prolonged period (e.g., years). Electrets are believed to be a relatively permanent source of an electric or electrostatic field. Thus, the rendering electret of a dielectric material in a cleaning sheet (e.g., particle retention layer, cover layer, backing layer, etc.) may thereby cause an electrostatic charge to build-up on the cleaning sheet. Such build-up of an electrostatic charge may enhance the ability of the cleaning sheet to attract, collect, trap and retain debris during the cleaning process. (Compare conventional non-electret materials, which typically only physically contact debris, with the debris adhering to, or being enveloped by, the conventional non-electret material.)

The application of an external electric field may render a dielectric material "electret". The molecules and charges in the dielectric are "polarized" or oriented in a certain direction or moment. The resulting electret is believed to possess an electric internal volume polarization that produces a permanent electrostatic field. The opposing outer faces of the electret exhibit opposite electrostatic charges. Since the internal molecules and charges are polarized, not merely exterior surface molecules and charges, the electrostatic orientation extends throughout the entire mass of the electret. Thus, the breaking or division of an electret yields multiple electrets (e.g., similar to the breaking of a permanent magnet).

Rendering a dielectric material electret can involve heterocharges, homocharges, or both, depending on the dielectric starting materials and the method of preparation. A "homocharge" as used in this disclosure is an electric charge on the dielectric of the

same sign as the polarity of an adjacent forming electrode. The forming electrode applies an electric field to the dielectric to render the dielectric "electret". Homocharges are believed to often develop in compounds containing esters and/or alcohols. A "heterocharge" as used in this disclosure is an electric charge on the dielectric of an opposite sign as the polarity of the forming electrode. Heterocharges are not typically stable. After the application of the electric field by the forming electrode, the charge of the heterocharge decreases until a polarity reversal occurs and an apparent equilibrium is reached. The resulting electret carries a surface charge (i.e., homocharge) that has the same polarity as the corresponding forming electrode.

i. Wax Electrets

Waxes may be rendered electret. The wax, in either an electret or non-electret state, may be applied to the cleaning sheet. One method for rendering a wax electret follows. According to the one method, suitable wax (shown as a paraffin 400 in FIGURE 10) in a molten state is poured into a condenser or mold (shown as a flat brass dish 402 covered with a wrap shown as a tin foil 404). A heater (shown as a gas burner 406) may facilitate melting of paraffin 400. Particularly suitable results may be obtained if paraffin 400 is melted to a thoroughly fluid state when the electric field is applied. According to an alternative embodiment, the electret may be formed without melting the wax. In such an embodiment, the wax is generally heated to attain a softened state before being exposed to the electric field.

As paraffin 400 is cooled (e.g., to about room temperature) and solidified, an electric voltage is applied by an electric field source 410. Electric field source 410 is shown having a positive forming electrode 412, a negative forming electrode 414 and a ground 416 electrically connected to condenser 402. Paraffin 400 solidifies under an electric stress at a sufficiently high potential to render paraffin 400 electrically "saturated". Some waxes may be rendered electret by electric fields as low as about 10 V/cm and in excess of fields as high as about 15 kV/cm. A high potential direct voltage of about 500-10000 V may be sufficient to permanently set the charge in the wax, another suitable voltage is about 1800 V, which corresponds to an electric field of about 11 kV/cm. (According to suitable embodiments, an AC or a DC current may produce the electric field.) The electric field may depend, in part, on the time required for the

wax to solidify. Suitable results may be obtained when the electric field is removed after paraffin 400 has thoroughly solidified, but still remains at an elevated temperature. According to another suitable embodiment, the charge is applied to paraffin 400 for about one hour.

Electrodes 412 and 414 may be any conventional electrode such as a tin, brass or copper disk having a diameter in the range of about 2-5 cm. Electrodes 412 and 414 may also be wrapped in foil 404 to inhibit soiling by paraffin 400, and foil 404 facilitates removal of paraffin 400 after solidification. After removing the electric field, a lower layer of foil 404 may be left on the resulting electret paraffin 400. An upper layer of foil 404 may be removed and replaced by a loose foil (not shown), arranged to "short" the electret. A cross-sectional view of the resulting electret paraffin 400 is shown in FIGURE 11. The wax may be rendered electret by other methods known to one of skill who reviews this disclosure.

Without intending to be limited to any particular theory, it is believed that when the electric field is applied to the paraffin, the molecules or clusters of the molecules orient themselves with their axes in the direction of the electric field so that, when the paraffin solidifies, the molecules retain their orientation. Such orientation of the molecules causes the paraffin to retain a permanent electric polarization (i.e., upon cooling molecular dipoles within the paraffin are "frozen" into an orientation determined by the field applied).

The resulting electret wax may have polarized charges present in an amount of at least about $5 \times 10^{-11}$ C/cm$^2$, suitably in the range of about $1 \times 10^{-10}$ C/cm$^2$ to $2 \times 10^{-9}$ C/cm$^2$ and possibly as high as about 30 kV/cm to 1.7 nC/cm2. The charge in the resulting electret wax is not believed to dissipate for a prolonged period. For example, U.S. Patent No. 2,284,039 predicts that an electret wax may remain electret for at least "a number of years". For additional information on the formation of electret waxes, see U.S. Patent No. 2,986,524 discussing the preparation of an electret wax, the disclosure of which is hereby incorporated by reference.

ii. Suitable Waxes

A "wax" as used in this disclosure is a substance that is a plastic solid at ambient temperature and becomes a low viscosity liquid when subjected to moderately elevated

temperatures. Suitable waxes are in the solid state at about room temperature and commonly have a melting point in the range of about 40 to 85°C to avoid melting, burning or softening of the cleaning sheet during manufacture. Examples of such suitable waxes include polyolefin, polyester and fluoropolymer waxes with melting points within this range. Other suitable waxes may have a melting point above about 85° C (e.g., carnauba wax), especially if applied to the cleaning sheet after the wax has been rendered "electret". An electret wax may lose its charge (e.g., the polarization of the charge may randomize) if the wax melts after being rendered electret. According to suitable embodiments, it may be advantageous to use wax that has a relatively low shrinkage coefficient on cooling. In order to avoid too great a degree of stiffness in the cleaning sheet, it is often advantageous to use a wax with a somewhat relatively lower melting point, e.g., within the range of about 45 to 70°C. This may also be accomplished by choosing a wax that has a relatively low penetration hardness value (as measured by ASTM D 1321).

Since waxes are relatively plastic, they tend to deform or flex under pressure with the application of relatively insubstantial heat. Suitable waxes such as paraffin are relatively malleable and may be applied to follow the contours of the cleaning sheet. Waxes having a greater hardness, such as carnauba wax, may also be acceptable. A wax that is too hard may "shear off" or be removed from the cleaning sheet during cleaning. Such removal of the wax from the sheet may disadvantageously transfer the wax from the sheet to the surface to be cleaned. The use of higher hardness wax can also tend to impart stiffness to the cleaning sheet. The stiffness of the sheet will of course be a function of a variety of parameters including the material used to form the particle retention layer, the configuration of this layer, the type of wax employed, the amount and positioning of the wax on the layer, etc. A suitable wax commonly has a penetration hardness of at least about 0.2 mm at 25°C, more typically about 0.5 to 3 mm at 25° C, as measured by ASTM D 1321, the disclosure of which is hereby incorporated by reference.

The color of the wax in the solid state is preferably white or clear, and does not easily degrade or discolor. Suitable colorless waxes include paraffin, hydrogenated waxes such as tristearin wax and other hydrogenated vegetable oils. Other suitable waxes include colored waxes such as beeswax and carnauba wax, which may have a

yellow-orange color. Natural waxes may be treated with a preservative according to suitable embodiments to inhibit degradation or contamination by bacteria and/or pests.

Suitable waxes should remain "electret" for a relatively prolonged period. Electret neutralizing variables such as moisture, humidity and ionization of ambient air may have a slight effect on such electret waxes. Normal atmospheric changes in temperature, humidity and altitude probably do not affect the electret wax significantly. Such neutralizing variables may be minimized by allowing them to "leak off" or dissipate within a relatively brief period (e.g. hours) to restore the effective charge on the electret. Such neutralizing variables may also be minimized by packaging with a desiccating material such as $CaCl_2$, by assumption of thin water layer or foil layer (e.g., short circuit) that shields the surface of the electret until removed, or by other methods known to one of skill who reviews this disclosure.

Suitable waxes are capable of carrying a permanent electric moment after charging by a forming electrode. Suitable categories of waxes include insect and animal waxes, such as beeswax secreted by bees. Beeswax has a melting point of 64° C, a hardness (penetration) of 2.0 mm at 25° C and 7.6 mm at 43.3° C. Suitable waxes also include vegetable waxes, resins and rosins. Vegetable waxes include, without limitation, candelilla, ouricury, Japan wax, ouricury wax, Douglas-fir bark wax, rice-bran wax, johoba, castor wax, bayberry wax and carnauba wax. Carnauba wax is in a solid state from room temperature to about 75°C, and in a liquid state above 83°C.

Suitable waxes also include mineral waxes. Mineral waxes include, without limitation, montan wax, peat waxes, ozokerite, ceresin waxes and petroleum waxes. Petroleum waxes include semicrystaline, microcrystalline and paraffin waxes. Microcrystalline waxes generally have a melting point within the range of 60-93°C, a viscosity ranging from 10-25 $mm^2/s$ at 98.9°C, and 30-75 carbon atoms per molecule. Paraffin waxes consist principally of alkanes, and typically have a melting range of about 45-70°C, a viscosity range of 4.2-7.4 $mm^2/s$ at 98.9°C, and 20-36 carbon atoms per molecule.

Suitable waxes also include synthetic waxes and asphaltums. Synthetic waxes include, without limitation, polyethylene waxes, Fischer-Tropsch waxes, chemically modified hydrocarbon waxes, substituted amide waxes, synthetic waxes such as

synthetic beeswax and synthetic sperm, oxidized polyethylene wax, hydrogenated johoba oil, and silicone waxes such as alkyl methyl siloxanes (silicone compounds).

Other suitable waxes include polyethylene waxes. Polyethylene waxes include low molecular weight (less than approximately 10,000) polyethylenes having wax-like properties, and are typically used in conjunction with petroleum waxes. Polyethylene waxes include, without limitation, olefin polymers, homopolymers of ethylene, copolymers of theyleen, propylene, butadiene and acrylic acid with wax-like properties. One polythylene wax includes Polywax 500® polyethylene synthetic hydrocarbon wax (commercially available from Petrolite Corporation of St. Louis, Missouri) having a melting point of 86°C, a hardness of 0.7 mm at 25°C and 6.1 mm at 60°C (according to ASTM D 1321). According to an alternative embodiment, the "wax" may be a polymer, such as a polyurethane, a polyethylene, and/or a fluorocarbons. Such polymers may be rendered electret without substantially raising the temperature beyond their melting points.

The wax may be relatively "pure" or used in combination with other waxes and materials. For example, suitable electrets may be prepared using waxes having equal weights of resin and carnauba, 40% rosin and 60% carnauba, or 45% colophony, 45% carnauba, and 10% beeswax (to recite a few). Other suitable electrets may be prepared using one part carnauba wax, one part rosin and one part beeswax. These proportions may be varied widely.

According to alternative embodiments, the wax may include minor proportions of other constituents such as ethyl cellulose (a white granular solid in which hydroxyl radicals of cellulose have been replaced by ethoxy group (OEt)), methacrylate resins (i.e., a solid ester of methacrylic acid polymerized by the action of heat, light or benzyl peroxide) and/or titanium compounds (e.g., titanium dioxide and barium titanate). The inclusion of a titanium compound may reduce the particle size of the constituents, such as carnauba wax, during the cooling period, and may decidedly increase the charges on the surfaces of the electret.

iii. Fibrous and Other Electrets

Fibers (e.g., woven and non-woven) and foams may be rendered "electret" directly (e.g., without the application of an electret wax). Fiber electrets may be

produced in a sheet or film form (or as a fiber) with one surface positively charged and the other surface negatively charged. For additional information on rendering fibers electret, see Bernard Gross, "Electret Devices for Pollution Control", State of the Art Review, Vol. 6, Optosonic Press 1972 (discussing the properties of electret materials), U.S. Patent No. 5,057,710 issued to Nishiura et al. (discussing a method for preparing electret materials), U.S. Patent No. 5,429,848 issued to Ando et al. (disclosing electret tubular non-woven fabric formed by catching the fibers carried by a fluid in a DC field), U.S. Patent No. 5,726,107 (discussing a non-woven electret fiber mixture including at least two types of electret fibers made from different materials) and U.S. Patent No. 4,486,365 (discussing a process and apparatus for the preparation of electret filaments, textile fibers and similar articles), the disclosures of each which are hereby incorporated by reference.

According to suitable embodiments, dielectric materials may also be rendered electret by ferroelectric effects, wherein a ferroelectric material exhibits oppositely polarized charge on its two surfaces because of applied pressure. According to other suitable embodiments, dielectric materials may be rendered electret by applying light (instead of a charge) at room temperature (e.g., illumination with 6000 lux of light). According to still other suitable embodiments, certain photoelectric insulating or semi-conducting materials may be rendered electret under the combined influence of illumination and a strong electric field. According to still other suitable embodiments, dielectric materials may be rendered electret by triboelectric effects.

b. <u>Materials of the Particle Retention Layer</u>.

The fibers used in the core are typically formed from thermoplastic materials. Thermoplastics materials are believed to retain an electrostatic charge for long periods, have relatively good insulating properties, and may be formed in a roll film, which permits continuous charging techniques. The fibers may also include semi-synthetic fibers (such as acetate fibers), regenerated fibers (such as cupra and rayon), natural fibers (such as cotton and blends of cotton), and other fibers or combinations of natural or synthetic fibers. The exterior of the fiber may be coated with an electret wax.

The base layer (i.e., core) may also be made of a porous sponge or foam as shown in FIGURE 2. Suitable foams include polyurethane foams and latex foams.

Such foams are typically prepared by using a blowing agent that reacts with a chemical to generate a gas (e.g., carbon dioxide), which is trapped as bubbles during a polymerization process, thereby forming the foam. Other suitable foams include phenolic resin foams. Phenolic resin foams are typically prepared by reacting phenol and formaldehyde in the presence of a basic catalyst, such as sodium hydroxide or potassium hydroxide, followed by neutralizing the solution and distilling off water. Such reaction is believed to produce resol (i.e., an A-stage resin) including reactive methol groups. The A-stage resin can by "cured" by reacting it further in the presence of an acid catalyst and in the presence of a blowing agent to form a phenolic resin. (During curing, some formaldehyde and water are typically liberated.) The reactive methol groups of the A-stage resin can react further to enlarge the polymeric chain length and/or cross-link to form a three-dimensional network.

The base layer (i.e., core) may be made of a fabric material (e.g., a continuous sheet) according to an exemplary embodiment as shown in FIGURE 4. The fabric may be woven, such as those traditional textile fabrics made by weaving (i.e., the interlacing of two or more yarn sets at right angles on a loom), or by knitting (i.e., the interlooping of one or more yarns upon itself or themselves). According to a suitable embodiment as shown in FIGURE 4, the fabric may be non-woven. Non-woven fabrics may be made by mechanically (such as by hydroentanglement), chemically or thermally interlocking layers or networks of fibers (or filaments or yarns). Interlocking fibers or filaments may also make non-woven fabrics concurrent with their extrusion and/or by perforating relatively thin films.

The materials of the core may be rendered electret by any variety of known methods. For example, the core materials can be rendered electret by coating them with an electret material such as a wax. The core materials may also be rendered electret by spinning fibers in a strong electrostatic field. The core materials may also be rendered electret by using triboelectret effects (i.e., inducing a charge by rubbing the fibers with other media). According to a suitable embodiment, at least 20% of the core materials are electret (by weight %), and in some instances as much as 50-100% of the core materials may be electret. The core materials have a charge suitably in the range of about $1.0 \times 10^{-11}$ to $1.0 \times 10^{-3}$ coulombs/cm$^2$, more suitably $1.0 \times 10^{-5}$ to $1.0 \times 10^{-3}$ coulombs/cm$^2$. The core material may have the capacity to retain debris having a size of

at least about 20 $g/m^2$. The electric charge of the core or other material of the cleaning sheet may affect the density of the particle intended to be collected, in part. The core may include non-electret natural or synthetic fibers to increase the breaking strength and elongation of the core. Such non-electret fibers may include, without limitation, wool, cotton, cellulose, polypropylene, polyethylene, polyester, polytetraflourine (PTE), nylon, rayon, acrylic, etc. and combinations thereof.

APPLICATION OF ELECTRET WAX TO THE CLEANING SHEET

An electret wax may be applied to the cleaning sheet, or any element of the cleaning sheet such as the core, cover, backing layer, etc. The wax is particularly suited for application on a fabric structure such as non-woven particle retention layer 330 as shown in FIGURE 5. The wax may be applied to the cleaning sheet, such as a non-woven cellulose paper towel, hydroentangled polyester, or PLEDGE® GRAB-IT™ sweeper cleaning cloth (commercially available from S.C. Johnson & Son, Incorporated of Racine, Wisconsin) before and/or after the wax has been rendered "electret". The wax may also be applied to a foam particle retention layer of the type shown in FIGURES 2-4, or a cover sheet (e.g., cover sheet 20 shown in FIGURE 2). According to another embodiment, the electret wax may be applied to a backing layer of a cleaning sheet (e.g., backing layer 20 as shown in FIGURE 4). According to other alternative embodiments, the wax may be applied to a central particle retention layer (e.g., of the type shown in FIGURES 2-5) to attract and collect debris through apertures of a cover layer.

Referring to FIGURE 12, a cleaning sheet 420 is shown having a woven (or alternatively non-woven) micro-fiber layer 422 attached to an electret layer 424. Electret layer 424 may be a woven or non-woven fabric material coated with an electret wax (or alternatively with fibers rendered electret by another method). Both electret layer 424 and micro-fiber layer 422 are particularly suited to cleaning dry surfaces. Microfiber layer 422 suitably is about 1-2 mm thick and is composed of fibers having denier in the range of about 0.1 to about 5. It may be advantageous to employ a microfiber layer formed from a mixture of relatively thicker microfibers having a denier of 1 to 3 and finer fibers having a denier of no more than about 0.9 and generally at least about 0.2 (preferably about 0.5 to 0.9).

The wax may be applied to the cleaning sheet according to a variety of methods and in a variety of configurations and patterns. Melted wax 434 may be "dripped" or applied as discontinuous spots or "islands" to a particle retention layer 432 of a cleaning sheet 430 as shown in FIGURE 13. Melted wax 434 may also be applied in a fluid spray (such as by an air spray gun) to particle retention layer 432 as a discontinuous pattern of droplets (as shown in FIGURE 13) or as a uniform spray, sheet or layer. According to a suitable embodiment, the wax may be combined with a solvent to decrease the viscosity of the wax, and sprayed on the particle retention layer. The solvent layer may then be "flashed off" or evaporated, leaving the melted or solidified wax on the particle retention layer. Suitable solvents for paraffin wax include toluene, benzene, other hydrocarbon solvents, chloroform, ether and mixtures thereof.

According to an alternative embodiment, melted wax 434 may be applied in a "bead" or row of corrugations 436 as shown in FIGURE 14. The wax may cover the exterior of the fiber on material on which it is applied, and may further impregnate or saturate or "soak" into the material 432 in whole or in part. The wax may collect between the intersections of the fibers, and/or may bond the fibers together. According to another alternative embodiment, melted wax 434 may be deposited in depressions 134 of particle retention layer 130 as shown in FIGURE 15. According to other alternative embodiments, the melted wax may be deposited in a single, continuous layer on any side or surface of the particle retention layer. According to a suitable embodiment, about 0.1 - 10 wt. % of the wax (relative to the dry weight of the particle retention material to which the wax is applied) may be applied to the particle retention layer, more suitably 0.5 - 5 wt %, most suitably about 0.7 – 2 wt.%. The weight of the wax is related in part to the area over which the wax may cover. According to a suitable embodiment, the wax covers at least about 10 % (relative to the surface area of the particle retention layer), more suitably at least about 30 to 50 %. It may be advantageous to leave a substantial percentage (e.g. 50% or more) of the particle retention layer untreated with the wax. The amount of wax applied preferably should render the material to which the wax is applied (e.g., particle retention layer) to have a particle retention capacity of at least about 20 $g/m^2$.

OUTER OR COVER LAYER

The present cleaning sheets may include a cover, which surrounds to covers a portion or the entire particle retention layer. Referring to FIGURE 2, core 30 is shown covered or surrounded by cover layer 20, such that core 30 is not substantially in contact with a work surface or surface to be cleaned 66. Cover layer 20 is substantially continuous and generally planar. According to an exemplary embodiment as shown in FIGURE 4, core 30 may be located between a top cover layer 322 and a bottom or backing layer 320 in a "sandwich" or packed fashion. Cover layer 322 is a generally smooth and compliant (e.g., flexible) generally planar sheet for cleaning delicate surfaces (e.g., wood, glass, plastic, etc.) or hard surfaces. According to other suitable embodiments, a space or other intermediate layers may be positioned between the core and the cover layer or layers.

The backing layer may be more rigid and/or have a greater basis weight than the core or the cover layer to provide support and structure to the cleaning sheet. According to other suitable embodiments, a space or other intermediate layer(s) may be positioned between the backing layer and the outer fabric layer. A variety of materials are suitable for use as a backing layer, as this layer has the desired degree of flexibility and is capable of providing sufficient support to the sheet as a whole. Examples of suitable materials for use as a backing layer include a wide variety of lightweight (e.g., having a basis weight of about 10 to 75 $g/m^2$), flexible materials capable of providing the sheet with sufficient strength to resist tearing or stretching during use. The backing layer is typically relatively thin (e.g., has a thickness of about 0.05 mm to about 0.5 mm) and can be relatively non-porous. Examples of suitable materials include spunbond and thermal bond non-wovens sheets formed from synthetic and/or natural polymers. Other backing materials that can be utilized to produce the cleaning sheet include relatively non-porous, flexible layers formed from polyester, polyamide, polyolefin or mixtures thereof. The backing layer could also be made of hydroentangled non-woven fibers, if it meets the performance criteria necessary for the particular application. One specific example of a suitable backing layer is a spunbond polypropylene sheet with a basis weight of about 20 to 50 $g/m^2$.

As shown in FIGURE 5, apertures (shown as holes 22) may be integrally formed in cover layer 322, which may be a continuous sheet of material. The holes may be circular shaped (as shown in FIGURE 7), but may be other shapes (e.g., rectangular, star, oval, irregular, etc.) or combinations of shapes according to alternative embodiments. Hole 122, another embodiment of hole 22, is shown having an irregular shape in FIGURE 8. According to a suitable embodiment, creating perforations in the cover layer may form the holes. Holes 22 are generally of a sufficient size to allow significantly sized debris (e.g., up to 0.5–100.0 mm) to pass through to the particle retention layer. After passing through the holes, the debris flows in the pores (i.e., cavities) of the particle retention layer. Each of holes 22 has a major diameter $D_1$ greater than any other diameter of the hole, and a secondary diameter $D_2$, which is the greatest cross-sectional axis perpendicular to major diameter $D_1$ (see, e.g., FIGURE 8). According to a suitable embodiment, the average major diameter of all of the holes may be in the range of about 1 to 10 mm, more suitably in the range of about 2 to 5 mm.

Each of holes 22 may have a cross-sectional dimension. The average cross-sectional dimension is equal to one-half of the sum of $D_1$ of the hole plus $D_2$ (i.e., average cross-sectional dimension = $(D_1 + D_2)/2$). The average cross-sectional dimension of each of the holes is typically at least about 1 $mm^2$, more typically in the range of about 1 to 100 $mm^2$, most suitably in the range of about 5 to about 25 $mm^2$. According to a suitable embodiment, the cross-sectional dimension of all the holes relative to the total surface area of the exterior surface of the cover layer is typically about 30% to 95% and more suitably 70% to 90%. The number of holes and the average cross-sectional dimension of the holes is selected to allow maximum amount of debris through the holes, while separating the core from the surface to be cleaned and maintaining the debris in the core.

The cover layer may be made of a material that has a low debris retention (i.e., that does not significantly attract or collect the debris) and generally has a lower debris retention than the core. According to a suitable embodiment, the cover layer may be made of a thermoplastic material. Thermoplastic materials or fibers may include, without limitation polyesters, polyamides and polyolefins, polypropylene, polyethylene, polystyrene, polycarbonate, nylon, rayon, acrylic, etc. and combinations thereof. The thermoplastic materials may be produced by a melt blown process. Other materials that

do not significantly attract debris include fibrous woven and non-woven fabrics having tightly packed fibers with a relatively high degree of entanglement coefficient. Still other such materials include non-fibrous materials such as a perforated polymer fibers or sheets. According to a suitable embodiment, the cover layer can be a spunbond or thermal bond polypropylene. According to other suitable embodiments, the cover layer may be made of natural materials (such as rubber, latex, and the like), as well as synthetic materials such as polyolefins (such as, polypropylene and polybutene), polyesters (such as polyethylene, polyurethane terephthalate and polybutylene terephthalate), polyamides (such as nylon 6 and nylon 66), acrylonitriles, vinyl polymers and vinylidene polymers (such as polyvinyl chloride and polyvinylidene chloride), and modified polymers, alloys or mixtures thereof, and other materials that have a relatively high dust retention capacity.

COUPLING OF THE COVER LAYER AND THE PARTICLE RETENTION LAYER

The cover layer may be attached to the core by a fastener such as melt bonding (shown as a stitch 126 in FIGURE 3). The fastener is intended to function as a way to bond (physically and/or chemically) or otherwise secure the cover layer to the core. According to a suitable embodiment, an adhesive may attach the cover layer to the core. The adhesive should be of a type that is relatively soft and non-abrasive relative to the surface to be cleaned. The adhesive should also permit the debris to pass through the apertures of the cover layer and should not substantiality retain the debris. The adhesive may be applied as a solid layer, a continuous pattern (e.g., a circle or serpentine pattern), a discontinuous pattern (e.g., a series of lines of a matrix of dots), or any other desired pattern such as checkerboard, cross, crisscross, etc. The adhesive material may be applied to the cover layer, the core, or to any other suitable intermediary surface (if any) or backing layer. According to other suitable embodiments, the cover layer, in whole or in part, and the core may be welded together (e.g., ultrasonic, infrared, melt bonding of thermoplastic in localized locations, spot welding, etc.). According to still other suitable embodiments, the cover layer may be attached to the core by entanglement (e.g., hydroentanglement) or by other fasteners (e.g., construction adhesives, clips, embossing, etc.).

DIMENSIONS OF THE CLEANING SHEET

The physical dimensions of the cover layer and the core are generally not thought to be critical. The outer perimeter of cover layer 20 is typically larger than the outer perimeter of core 30, as shown in the FIGURES, so that debris 68 may pass through holes 22 of cover layer 20 before being retained in core 30. Cover layer 20, as shown in FIGURE 2, has a thickness $T_1$ that is typically less than a thickness $T_2$ of core 30. By way of a non-limiting example, the cover layer can have an average thickness of up to about 1 mm, preferably 0.05 to 0.5 mm. The core can have an average thickness up to about 5 mm, preferably 1 to 2 mm. According to a suitable embodiment as shown in FIGURE 1, cover layer 20 has a shape and configuration similar to that of core 30. The cleaning sheet may have a length of about 8 inches and a width of about 12 inches.

CLEANING IMPLEMENTS AND METHODS OF USE

Pad 10 may be used alone (e.g., as a rag) or in combination with other implements and utensils to clean surface 66. Pad 10 is generally flexible for following any contour (e.g., smooth, jagged, irregular, creviced, etc.) of a surface 66 to be cleaned. Accordingly, pad 10 is particularly suitable for cleaning hard, rigid surfaces. According to another embodiment, pad 10 may be semi-rigid and particularly suitable for cleaning planar surfaces. Pad 10 may also be used to clean relatively soft surfaces such as carpets, rugs, upholstery and other soft articles.

Referring to FIGURE 1 pad 10 is shown attached to a cleaning head 62 of a cleaning utensil (shown as a dust mop 60) according to an exemplary embodiment. Head 62 includes a carriage 80 providing a fastener (shown as a spring clip 82) for mounting pad 10. A mounting structure 84 attaches an elongate rigid member (shown as a segmented handle 64) is attached to carriage 80. Mounting structure 84 includes a yoke (shown as an arm 86) having a y-shaped end 88 pivotally mounted to a socket (shown as a ball joint 90). An adapter (shown as a connector 92) threadably attaches arm 86 to handle 64. According to suitable embodiments, the cleaning utensil may be a broom, brush, polisher, handle or the like adapted to secure the cleaning sheet. The cleaning sheet may be attached to the cleaning utensil by any of a variety of fasteners (e.g., friction clips, screws, adhesives, retaining fingers, etc.). According to other suitable embodiments, the cleaning sheet may be attached as a single unit, or as a plurality of sheets (e.g., strips or "hairs" of a mop).

The components of the cleaning utensil, namely the mounting structure, adapter, handle, and wax that has been rendered electret may be provided individually or in combinations (e.g., as a kit or package). The components of the cleaning utensil may be readily, easily and quickly assembled and disassembled in the field (e.g., work site, home, office, etc.) or at the point of sale for compactablity and quick replacement. The cleaning utensil may also be provided in a pre-assembled and/or unitary condition. According to a suitable embodiment, the cleaning sheet is configured for use with the PLEDGE® GRAB-IT™ sweeper (commercially available from S.C. Johnson & Son, Incorporated of Racine, Wisconsin).

To clean surface 66, pad 10 may be secured to head 62 of mop 60 by clip 82. Pad 10 is brought into contact with surface 66 and moved along surface 66 (e.g., in a horizontal direction, vertical direction, rotating motion, linear motion, etc.). Debris 68 from surface 66 is provided or attracted through holes 22 in cover layer 20. An electrostatic charge of an electret material in core 30 may pull or draw debris 68 through holes 22 of cover layer 20 and into core 30 (see FIGURE 2). Pores (shown as cavities 34) of core 30 retain and/or entrain debris 68 within cavities 32 of pad 10. The exterior surface of cover layer 20 does not substantially attract or retain debris 68, so the exterior surface of cover layer 20 of pad 10 remains substantially free of debris 68. After use, pad 10 may be removed from mop 60 for disposal or cleaning (e.g., washing, shaking, removing debris, etc.). According to other suitable embodiments, the cleaning sheet may be used alone (e.g., hand held) to clean the surface. According to an alternative embodiment as shown in FIGURE 1, an electret wax may be applied to pad 10 at room temperature.

INDUSTRIAL APPLICABILITY

The cleaning sheet of the present invention can be manufactured using commercially available techniques, equipment and material. In addition, the cloth may be used on a variety of surfaces such as plastic, wood, carpet, fabric, glass and the like. Cleaning implements and methods of cleaning surfaces using the cleaning sheet are also provided herein. The cleaning implement may be produced as an intact implement or in the form of a cleaning utensil kit. Intact implements include gloves, dusters and rollers. Kits according to the present invention, which are designed to be used for cleaning surfaces, commonly include a cleaning head and a cleaning sheet capable of being

coupled to the cleaning head. In addition, the kit can include a yoke capable of installation on the cleaning head and an elongate handle for attachment to the yoke. Whether provided as a completely assembled cleaning implement or as a kit, the cleaning implement may include a cleaning head that allows the cleaning sheet to be removably attached to the cleaning head.

TEST METHODS

c. Breaking strength (cross machine direction)

From each of the cleaning sheets, samples having a width of 30 mm may be cut out in the direction perpendicular to the fiber orientation in the sheet (i.e., in the cross machine direction). The sample may be chucked with a chuck-to-chuck distance of 100 mm in a tensile testing machine and elongated at a rate of 300 mm/min in the direction perpendicular to the fiber orientation. The value of load at which the sheet began to break (the first peak value of the continuous curve obtained by the stress/strain measurement) may be taken as the breaking strength.

d. Elongation at a load of 500 g/30 mm

The elongation of a sample, at a load of 500 g in the measurement of the breaking strength in the cross machine direction described above, may be measured. For the purposes of this test, "elongation" is defined as the relative increase in length (in %) of a 30 mm strip of cleaning sheet material when a tensile load of 500 g is applied to the strip.

c. Entanglement Coefficient

The scrim may be removed from the non-woven fiber aggregate. Where the scrim has a lattice-like net structure, this is typically accomplished by cutting the fibers which make up the network sheet at their junctures and carefully removing the fragments of the network sheet from the non-woven fiber aggregate with a tweezers. A sample having a width of 15 mm may be cut out in the direction perpendicular to the fiber orientation in the sheet (i.e., in the cross machine direction). The sample may be chucked with a chuck-to-chuck distance of 50 mm in a tensile testing machine, and elongated at a rate of 30 mm/min in the direction perpendicular to the fiber orientation (in the cross machine direction). The tensile load value F (in grams) with respect to the elongation of the sample may be measured. The value, which is obtained by dividing the tensile load value F by the sample width (in meters) and the basis weight of the non-

woven fiber aggregate W (in $g/m^2$), is taken as the stress, S (in meters). A stress-strain curve is obtained by plotting stress ("S") against the elongation ("strain" in %) (i.e., stress S [m] = (F/0.015)/W).

For a non-woven fiber aggregate, which is held together only through the entanglement of the fibers, a straight-line relationship is generally obtained at the initial stage of the stress-strain (elongation) curve. The gradient of the straight line is calculated as the entanglement coefficient E (in meters). For example, in the illustrative stress-strain curve shown in FIGURE 9 (where the vertical axis represents the stress, the horizontal axis represents the strain, and O represents the origin), the limit of straight-line relationship is represented by P, the stress at P is represented by $S_p$, and the strain at P is represented by $\gamma_p$. In such cases, the entanglement coefficient is calculated as $E = S_p/\gamma_p$. For example, when $S_p = 60$ m and $\gamma_p = 86\%$, E is calculated as $E = 60/0.86 = 70$ m. It should be noted that the line OP is not always strictly straight. In such cases, a straight line approximates the line OP.

Although only a few exemplary embodiments have been described, the present invention is not limited to one particular embodiment. Indeed, to practice the invention in a given context, those skilled in the art may conceive of variants to the embodiments described herein (e.g., variations in sizes, structures, shapes and proportions of the various elements, values of parameters, mounting arrangements, or use of materials) without materially departing from the true spirit and scope of the invention. Various modifications may be made to the details of the disclosure without departing from the spirit of the invention.

WHAT IS CLAIMED IS:

1. A cleaning sheet for cleaning and removing particles from a surface comprising a particle retention layer for collecting and retaining the particles; wherein the particle retention layer includes electret wax.

2. The cleaning sheet of claim 1 wherein the electret wax has a melting point of at least 40°C.

3. The cleaning sheet of claim 1 wherein the particle retention layer includes at least 0.1 wt.% of the electret wax.

4. The cleaning sheet of claim 3 wherein the particle retention layer includes no more than 10 wt.% of the electret wax.

5. The cleaning sheet of claim 1 wherein the electret wax is present on at least a portion of an exterior surface of the sheet.

6. The cleaning sheet of claim 5 wherein the electret wax is present on at least 10 % of the exterior surface.

7. The cleaning sheet of claim 1 wherein at least a portion of the particle retention layer is impregnated with the electret wax.

8. The cleaning sheet of claim 1 wherein the particle retention layer has a charge of at least $1.0 \times 10^{-11}$ C/cm$^2$.

9. The cleaning sheet of claim 1 wherein the particle retention layer includes a dust retention material selected from the group consisting of woven fabrics, non-woven fabrics, foams, and combinations thereof.

10. The cleaning utensil of claim 1 wherein the particle retention layer includes a non-electret material.

11. The cleaning sheet of claim 1 wherein the particle retention layer includes fibers and the wax is deposited on the exterior of at least some of the fibers.

12. The cleaning sheet of claim 1 wherein the particle retention layer is a microfiber layer.

13. The cleaning sheet of claim 1 wherein the particle retention layer has a particle retention capacity of at least about 20 $g/m^2$.

14. The cleaning sheet of claim 1 having a breaking strength of at least about 500 g/ 30 mm.

15. The cleaning sheet of claim 1 having an elongation of no more than about 25 % at a load of 500 g/30.0 mm.

16. The cleaning sheet of claim 1 having a basis weight of about 50 to 250 $g/m^2$.

17. The cleaning sheet of claim 1 coupled to a mounting structure.

18. The cleaning sheet of claim 1 wherein the wax has a penetration hardness of at least 0.2 at 25°C.

19. A method of making a cleaning sheet comprising:
forming a sheet from a particle retention material comprising at least one of a woven fiber, a non-woven fiber or a foam;

applying a non-electret wax to at least a portion of the particle retention material;
applying an electric field to the sheet of particle retention material to render the wax electret.

20. The method of claim 19 further comprising heating the sheet of particle retention material to a temperature sufficient to soften the wax;

applying the electric field to the sheet of particle retention material while the wax is in the softened state; and

cooling the sheet of particle retention material sufficiently to solidify the wax.

21. The method of claim 19 further comprising heating the sheet of particle retention material to a temperature sufficient to melt the wax;

applying the electric field to the sheet of particle retention material while the wax is in the softened state; and

cooling the sheet of particle retention material sufficiently to solidify the wax.

22. The method of claim 21 comprising heating the sheet of particle retention material to a temperature sufficient to melt the wax without softening the particle retention material.

23. The method of claim 19 comprising applying the non-electret wax to the sheet in a discontinuous pattern.

24. The method of claim 19 comprising applying the non-electret wax to the sheet in a continuous pattern.

25. The method of claim 19 wherein applying the non-electret wax includes spraying a mixture which includes the wax and a solvent on the sheet.

26. A method of making a cleaning sheet comprising:

forming a sheet from a particle retention material comprising at least one of a woven fiber, a non-woven fiber or a foam;

spraying molten wax onto at least a portion of the sheet of particle retention material such that the molten wax passes through an electric field; and

cooling the molten wax to form solidified electret wax.

27. A cleaning utensil for collecting and retaining debris comprising:

a cleaning head;

a cleaning sheet adapted for coupling to the head including:

a particle retention layer for collecting and retaining the particles; wherein the particle retention layer includes electret wax.

26. A kit for cleaning surfaces and collecting and retaining debris comprising

a cleaning head;

a cleaning sheet adapted for coupling to the head, the cleaning sheet including a particle retention layer for collecting and retaining the particles; wherein the particle retention layer includes electret wax.

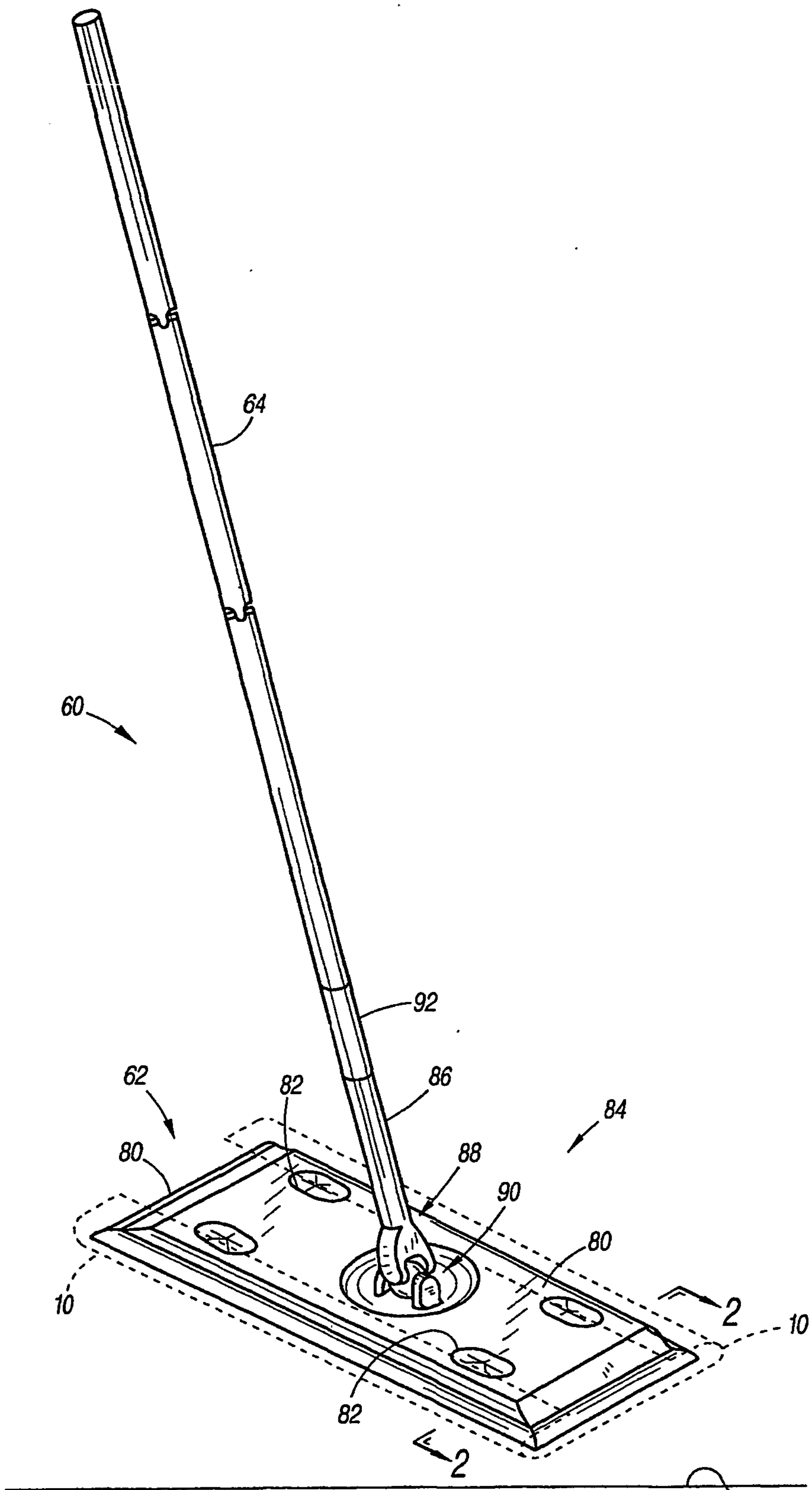


FIG. 1

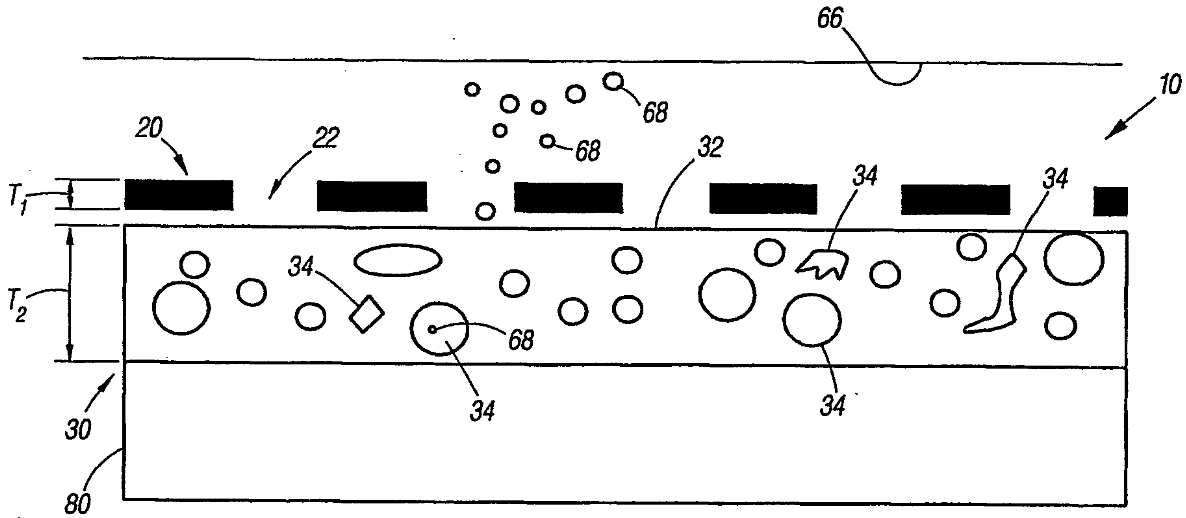
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FIG. 2

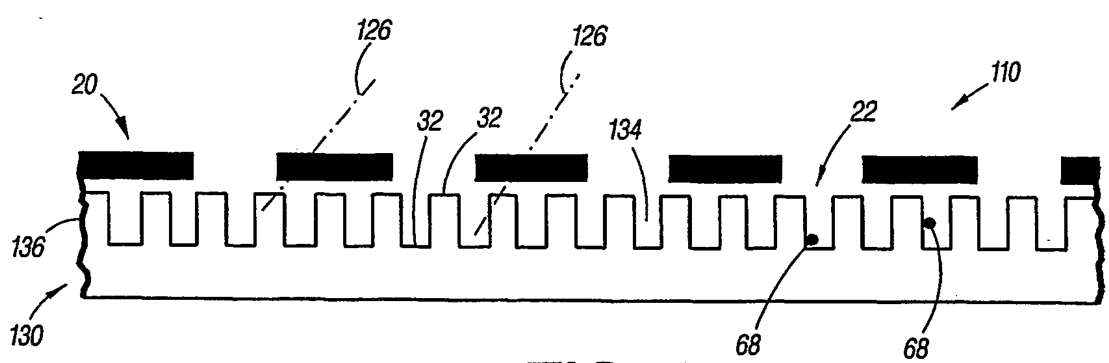
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FIG. 3

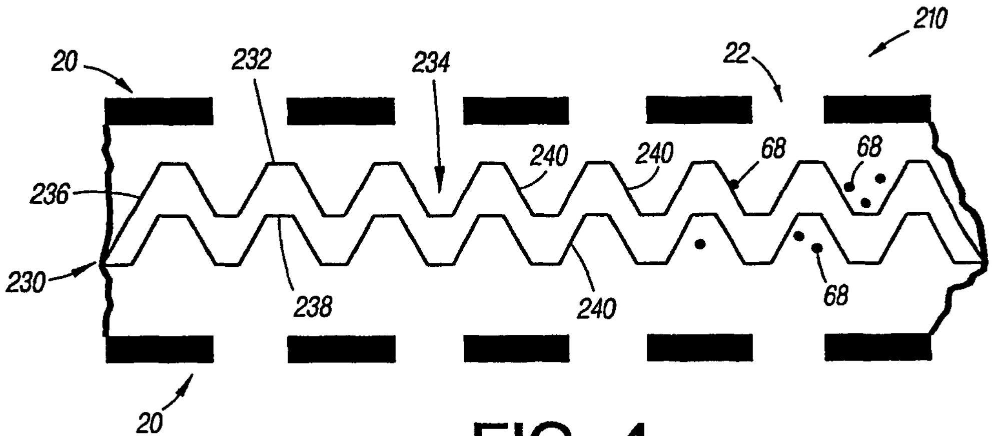
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FIG. 4

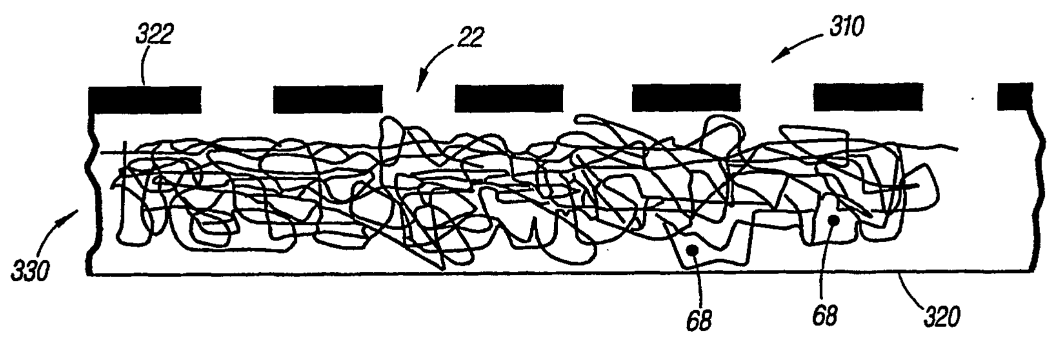
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FIG. 5

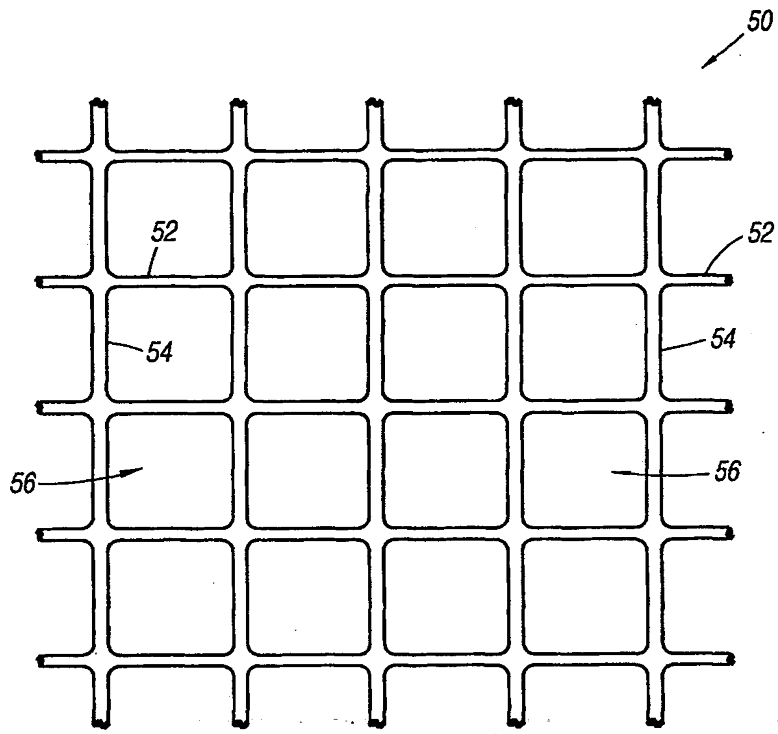


FIG. 6

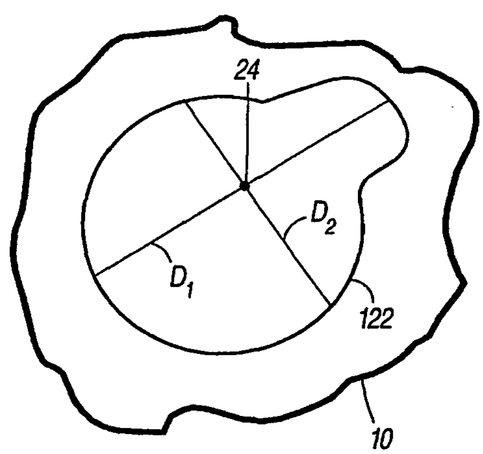


FIG. 8

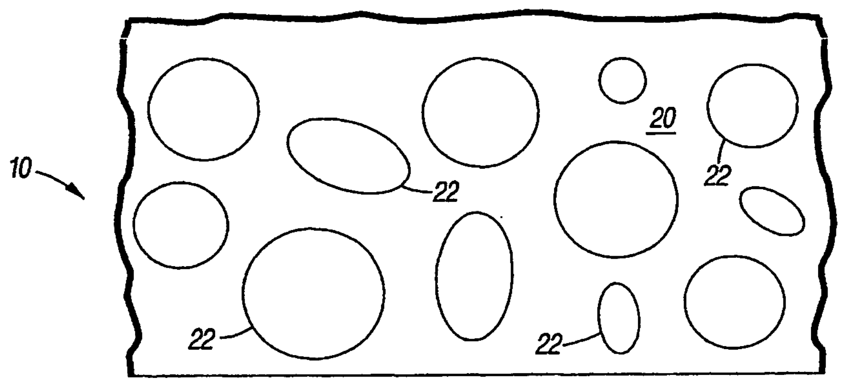


FIG. 7

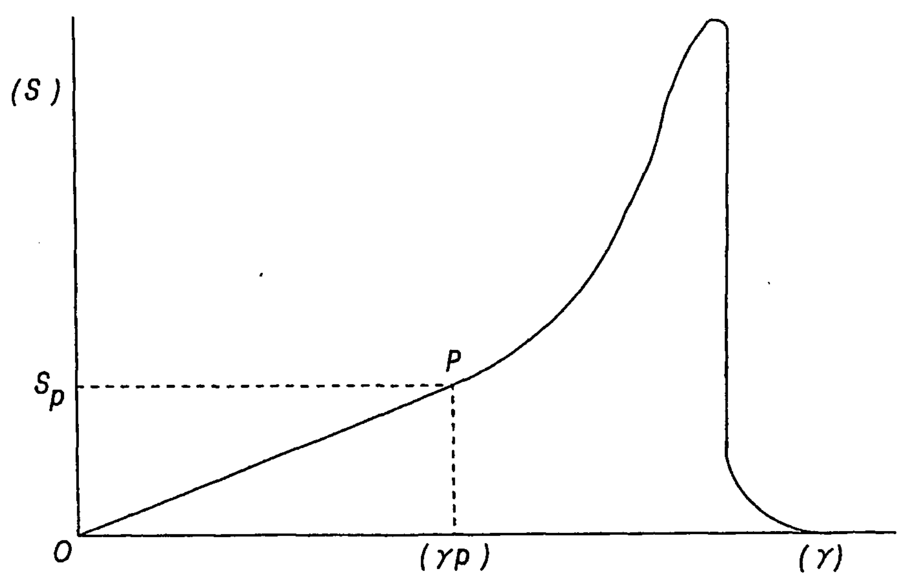


FIG. 9

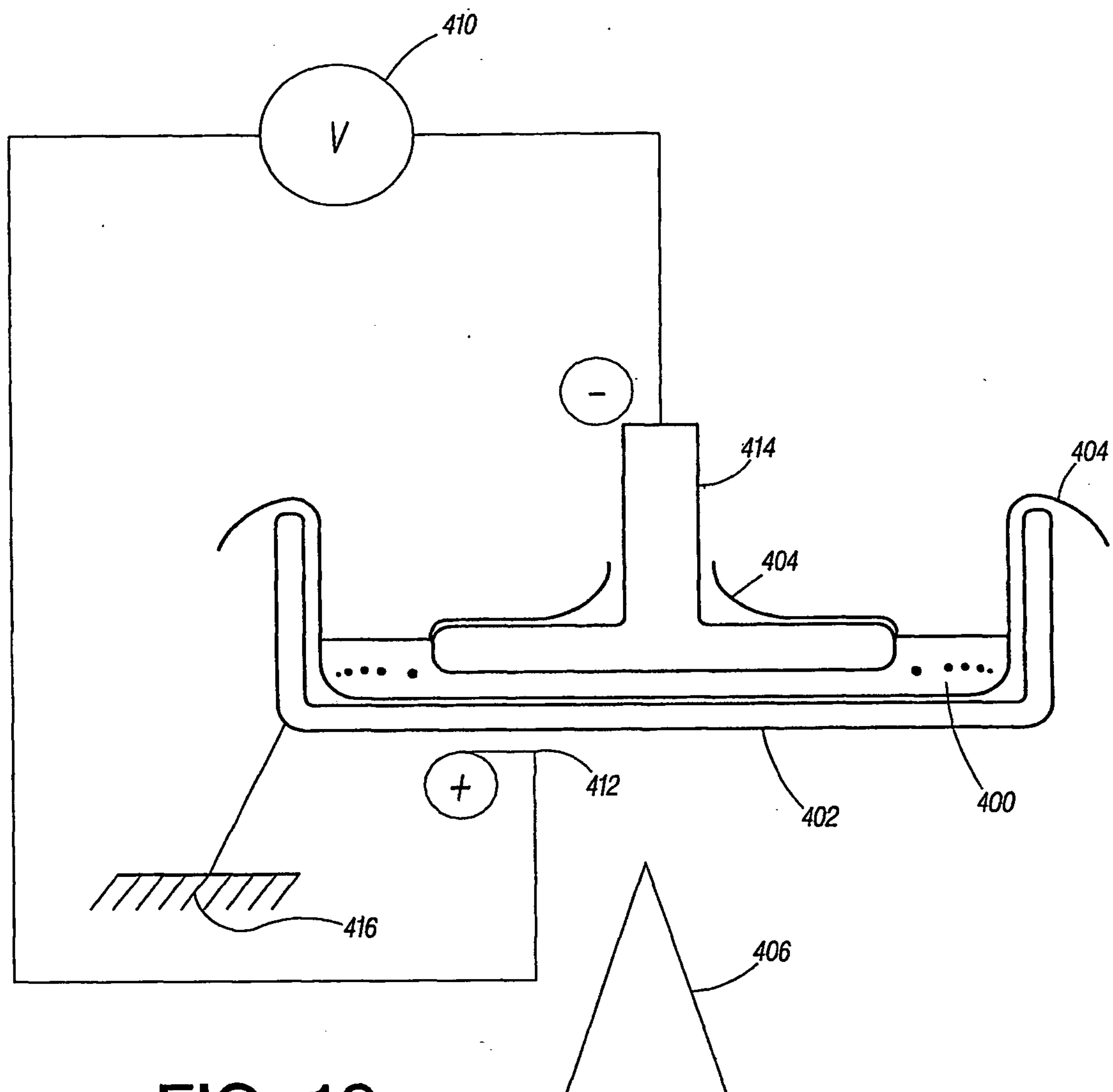


FIG. 10

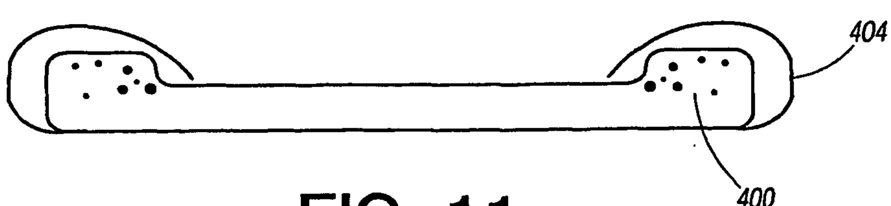


FIG. 11

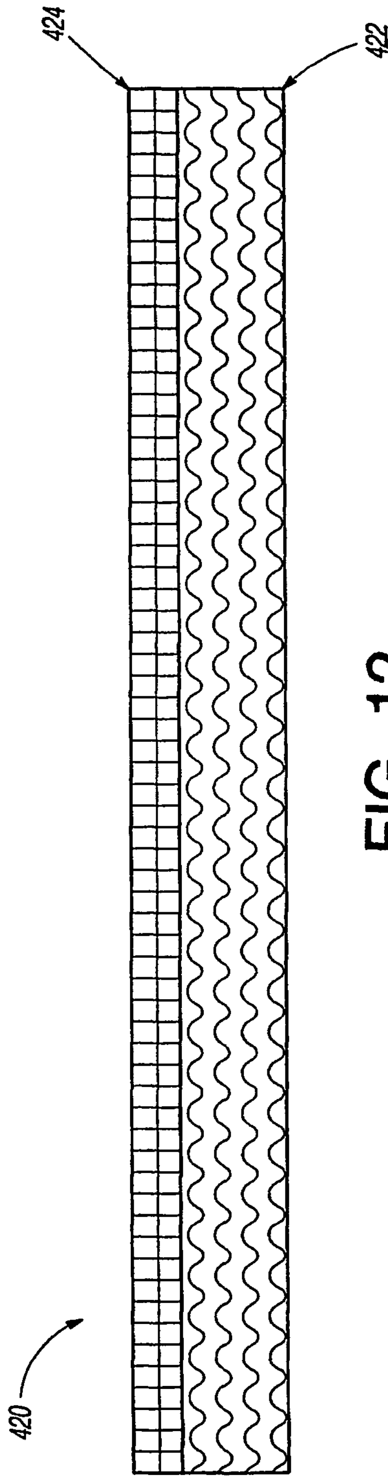


FIG. 12

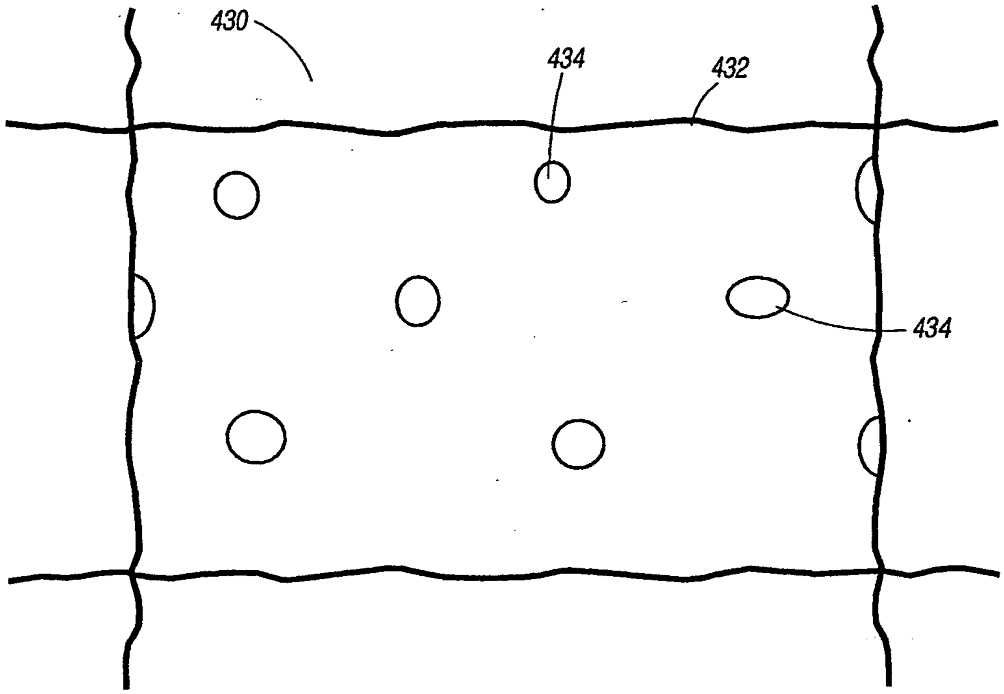


FIG. 13

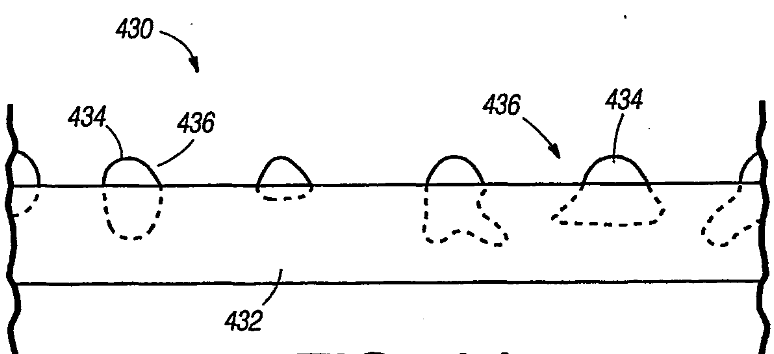


FIG. 14

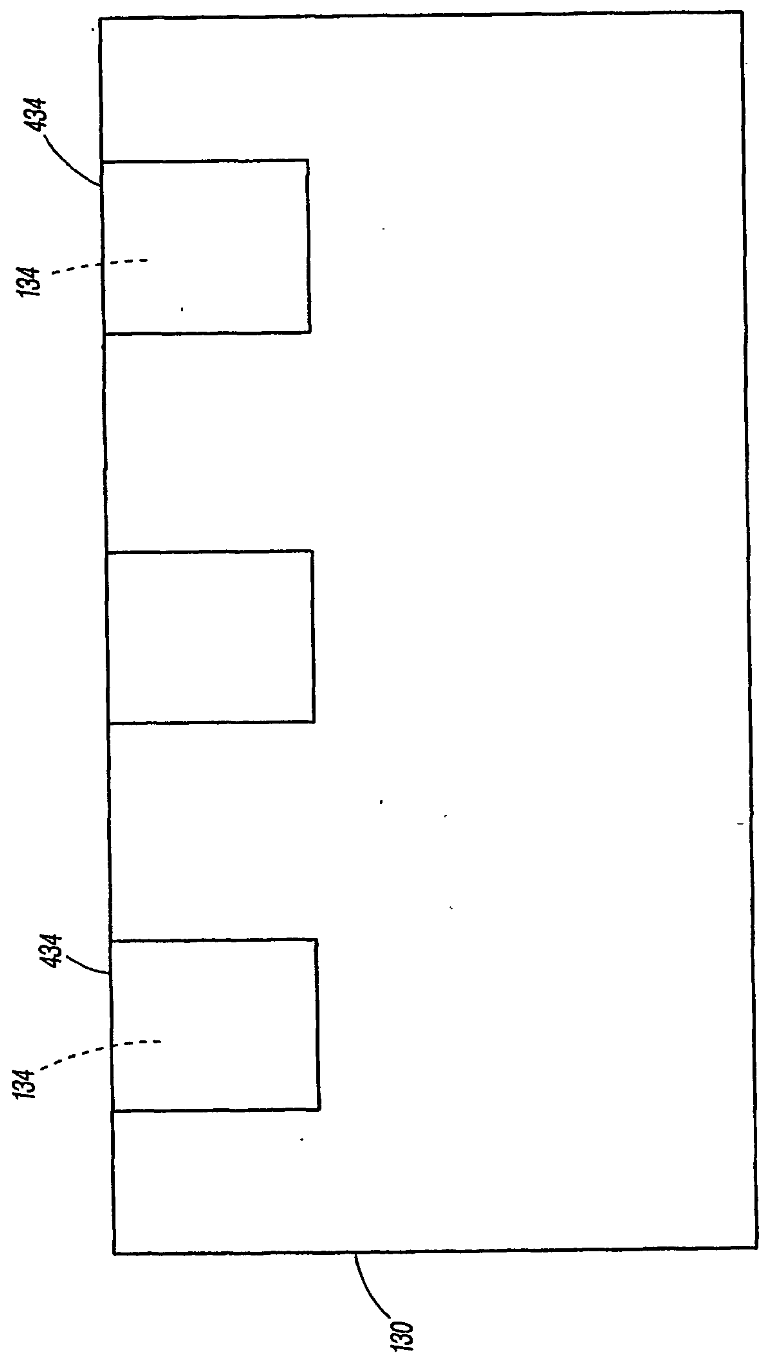


FIG. 15

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(74) Agents: FRANK, J., William et al.; Patent Section, S.C. Johnson & Son, Inc., 1525 Howe Street, Racine, WI 53403 (US).

(81) Designated States *(national)*: AU, BR, CA, CN, CZ, HU, JP, KR, MX, NZ, PL, RU, SG, SK, UA, ZA.

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**Published:**
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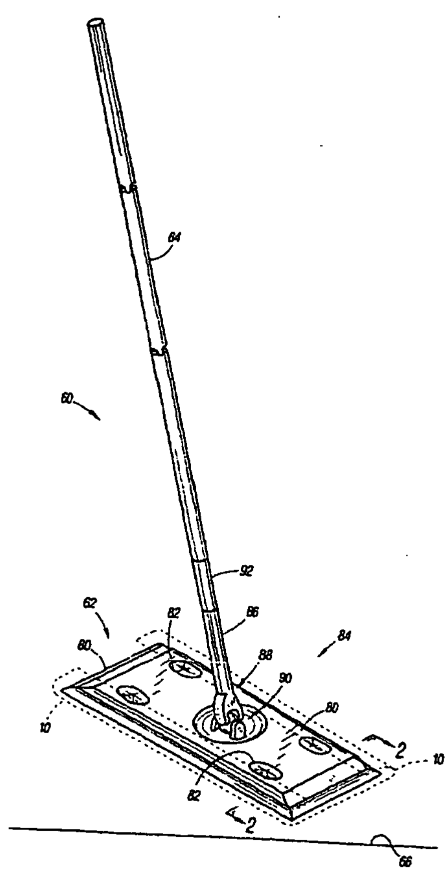
*[Continued on next page]*

(54) Title: PARTICLE ENTRAPMENT SYSTEM




**(57) Abstract:** A cleaning sheet for cleaning and removing particles from a surface is disclosed. The cleaning sheet includes a particle retention layer for collecting and retaining the particles. The particle retention layer includes electret wax deposited on at least a portion of the layer.

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*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

# INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 01/20132

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC 7 D06M10/00 D06M10/04 D06M10/06 D06M10/10 D06M10/08
A47L13/16

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 D06M A47L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | US 5 956 798 A (TAKESAKO KIYOYUKI ET AL) 28 September 1999 (1999-09-28) column 2, line 38 - line 48; claims | 1-19,27, 28 |
| A | US 5 198 292 A (LERNER PETER ET AL) 30 March 1993 (1993-03-30) the whole document | 1-19, 26-28 |
| A | US 3 144 671 A (GOULD ARTHUR S ET AL) 18 August 1964 (1964-08-18) claims | 1,27,28 |
| A | US 3 448 478 A (NASH LAWRENCE M ET AL) 10 June 1969 (1969-06-10) column 3, line 7 | 1,19, 26-28 |

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[X] Patent family members are listed in annex.

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| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 15 February 2002 | 27/02/2002 |

| Name and mailing address of the ISA | Authorized officer |
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| European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,<br>Fax: (+31-70) 340-3016 | Blas, V |

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| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | US 2 986 524 A (PADGETT EDWARD D) 30 May 1961 (1961-05-30) cited in the application the whole document | 19-21 |
| A | DATABASE WPI Section Ch, Week 199439 Derwent Publications Ltd., London, GB; Class A17, AN 1994-314206 XP002190386 -& JP 06 240551 A (ASAHI KASEI KOGYO KK), 30 August 1994 (1994-08-30) abstract | 1,27,28 |
| A | DATABASE WPI Section Ch, Week 199351 Derwent Publications Ltd., London, GB; Class A88, AN 1993-408340 XP002190387 -& JP 05 305049 A (DUSKIN CO LTD), 19 November 1993 (1993-11-19) abstract | 1,27,28 |

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 01/20132

| Patent document cited in search report | | Publication date | Patent family member(s) | | Publication date |
|---|---|---|---|---|---|
| US 5956798 | A | 28-09-1999 | JP | 10057728 A | 03-03-1998 |
| US 5198292 | A | 30-03-1993 | US | 5198293 A | 30-03-1993 |
| US 3144671 | A | 18-08-1964 | NONE | | |
| US 3448478 | A | 10-06-1969 | DE | 1635222 A1 | 01-07-1971 |
| | | | NL | 6709171 A | 02-01-1968 |
| | | | US | 3630800 A | 28-12-1971 |
| US 2986524 | A | 30-05-1961 | NONE | | |
| JP 6240551 | A | 30-08-1994 | NONE | | |
| JP 5305049 | A | 19-11-1993 | JP | 2930472 B2 | 03-08-1999 |